The use of RDT in the HAIC project

Jean-Marc Moisselin, Météo-France
jean-marc.moisselin@meteo.fr
--------------------------------
co-authors: Christine Le Bot (Météo-France), Pierre Rieu (Météo-France), Amanda Gounou (Météo-France), Eric Defer (CNRS/LA), Jos De Laat (KNMI)
--------------------------------
speaker: Jean-Marc Moisselin, Météo-France

Introduction
The European FP7 (Seventh Framework Program) HAIC (High Altitude Ice Crystals) 2012-2017 project aims at characterizing specific environmental conditions in the vicinity of convective clouds that can lead to aeronautical events linked to high-altitude mixed phase and glaciated icing.

RDT (Rapidly Developing Thunderstorm) is a software developed by Météo-France in the framework of NWCSAF (Satellite Application Facility for Nowcasting). RDT detects, tracks and characterizes convective systems. High IWC (Ice Water Content) is often associated with deep convection and especially strong updrafts that inject important quantities of water into the upper troposphere.

The paper will describe the different uses of RDT in the framework of HAIC. During the HAIC campaigns RDT operated by Météo-France has been used by research aircraft pilots to target the convective cells. After the campaign the performances of RDT regarding the high IWC hazard have been assessed.

The RDT tool
Figure 1 explains the various input data of RDT: geostationary satellite Brightness Temperature (BT), large scale NWP (Numerical Weather Product), lightning data, other NWCSAF products. Only the BT of the channel 10.8µm (or equivalent) is mandatory.
For the first HAIC campaign (2014) located at Darwin (Australia), RDT was adapted to use the observations of MTSAT-1R imager, at a frequency of 10 minutes [Moisselin et al, 2014]. The version v2012 [Auçonès, 2012] was adapted and used the channels 6.7 and 10.8 µm. Some missing input data sets had an impact on the RDT behaviour and performances.

During the Cayenne 2015 campaign, RDT was adapted to be operated with MSG-SEVIRI imager on the campaign domain, with five channels. By using MSG-SEVIRI imager, parallax effects are much larger because the Cayenne campaign domain is located at the border of the SEVIRI coverage. Despite this problem, the choice to base RDT on SEVIRI data has been made because of the lower resolution time of the imager of GOES satellite, and the lack of some wavelength channels. SEVIRI data were available every 15 minutes instead of 30 minutes for GOES imager. The RDT version v2013 [Auçonès et al, 2013] has been used for this campaign and the followings.

After a first attempt in Indonesia, Darwin was chosen to be the location of the last HAIC field campaign for the beginning of 2016. RDT has been adapted to handle the imager data from the satellite HIMAWARI-8. A lookup table of channels from Himawari-8 imager to channels from MSG-SEVIRI imager has been used. However at Darwin, at this time of the year, favourable convective conditions were not present most of the time. It was then decided to move the field campaign to La Réunion. So the campaign moved to La Réunion, where Meteosat7-based RDT was used. It gave the opportunity to cross cells with very high ice crystals concentrations. However, as Meteosat7 is an older satellite, RDT only uses one satellite channel (channel 11.5 µm).

To sum-up one can say that RDT has been operated in the most valuable conditions during the Cayenne 2015 campaign.

**RDT used for supporting the flight campaigns**

One of the objectives of RDT was to target the convective areas for the research aircrafts. RDT was successfully tested during the first HAIC/HIWC field campaign in Darwin in 2014 on best effort, the output has been adapted to make the uplink faster for the small bandwidth of IRIDIUM Short Burst Data satellite communication.

RDT was used by forecasters of each campaign for the meteorological ground-support for example through a dedicated website or though the Synergie Météo-France forecasters’
workstation during Cayenne 2015 campaign. Other kinds of meteorological information were available [Moisselin et al, 2016]: radar data, lightning data, NWP data, etc. The field campaigns gave the opportunity to uplink data on-board thanks to the ATMOSPHERE PLANET system and it has been effective from the Cayenne-2015 campaign. A special effort has been made on operational aspects. Indeed, the main elements of the production chain have been secured and monitored [Gounou et al, 2016]. The convective RDT outlines are completed by a series of parameters that represent much less data to transfer than a regular satellite image. This information combined with a reduced list of RDT attributes can be uplinked on-board in XML format and then can be used by the pilots in real-time mode. RDT data have been sent to the PLANET system developed by ATMOSPHERE company during the Cayenne campaign, as illustrated in Figure 2 [Gounou et al, 2016]. This development allowed to enhance the vision of surrounding convective areas for pilots.

![Figure 2: Description of the RDT process up to the uplink to research aircrafts.](image)

**RDT a tool for detecting high IWC**

RDT has been mainly compared with two measurement or retrieval of high IWC: the Robust Probe and the DARDAR product. The Robust probe samples the Total Water Content during the flights. It has been placed on the Falcon aircraft during Darwin 2014, Cayenne2015, and on the Airbus A340 during the campaigns of the year 2016. The deliverables D13.2 [Schwarzenboeck et al, 2014] describes the data collected during the HAIC/HIWC campaign. DARDAR (raDAR/lidar) product is the combination of coincident space-borne Cloudsat radar (95 GHz) and CALIPSO lidar (532 & 1064 nm) A-Train Low Earth Orbit (LEO) observations. It is sensitive to different properties of the clouds (phase, particle size distribution). It has the capability to retrieve the vertical distribution of IWC inside the clouds [Delanoé et al, 2010]. The time resolution of RDT data and in-situ measurements is different. For example RDT is available every 15 minutes for the Cayenne campaign while in-situ measurements from the ROBUST probe are available every second. The pairing method describes which cells will be selected for the comparison with a given one-second observation. Four methods are proposed; they are described below (table 1) and summarized in [Moisselin et al, 2017b].
Table 1: Description of the pairing methods between RDT cells and in-situ measurements.

<table>
<thead>
<tr>
<th>Meth.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Minimizes the time-difference between measurements and satellite image</td>
</tr>
<tr>
<td>1B</td>
<td>-To take into account the blinking effect of RDT (dynamic detection)</td>
</tr>
<tr>
<td>1C</td>
<td>-To assess the nowcasting potential of RDT concerning IWC risk</td>
</tr>
</tbody>
</table>

Cells of contingency table on which the scores have been calculated is given in Figure 3.

Figure 3: RDT cells and in-situ measurements. The background image is a 10.8 µm enhanced image where lower BT are shaded in blue. The RDT outlines are in red. The flight trajectory is coloured accordingly to in-situ IWC measurement with the highest values in bright blue.

The overall PODs for the Cayenne campaign with method 1A are relatively good (Figure 4):

- For 11 flights out of the 16 flights of the campaign, POD is higher than 0.7 for the IWC threshold of 1 g/m³.
- For 8 flights, POD is higher than 0.8
- For 4 flights, POD reaches more than 0.9.
- For these last 4 flights, the FAR stays below 0.66, which corresponds to a good agreement between RDT cells and areas where IWC is above the threshold.
Only five flights have a POD lower than 0.5 (for a threshold of 1 g/m³).
Quite naturally, in comparison with method 1, POD associated with method 1B is increased for all flights. The impact is not the same for all flights: POD for flight 22 is increased by more than 15% whereas POD does not improve for flight 13 (Figure 4).
The Method 1C is similar to method 1B: it considers RDT cells from the closest satellite slot in time and the two previous ones. This way to consider the RDT cell has low or no impact on the result, except for the flights number 11 and number 16. Again, POD has increased compared with method 1B (flight 10 is a good example). Since we have more cells, FAR tends to also increase with methods 1B and 1C.
The method 2 is intended to compensate some too early declassification of mature systems regarding high IWC hazard. In fact, it is obvious, especially for flights 11 and 16, that declassified cells sometimes contain high concentrations of ice crystals. POD for those two flights has increased by 50 % with this method. POD of some other flights has also slightly improved. The interest of method 2 is proven for two flights (Figure 5).
Scores for all campaigns and DARDAR are given in [Moisselin et al, 2017b]. Results for the Darwin 2014 campaign are better because the convective cells were large and stationary (see Table 2). During the Cayenne campaign, the convective situation is more complex but the POD remains at an acceptable level. For the Darwin 2016 and La Réunion campaigns the RDT evaluation suffers of the size of the sample.

Concerning the DARDAR comparison, the scores are not bad and the impression given by the path by path analysis confirms it. It illustrates also the gap in terms of verification sampling between a flight campaign focusing on big convective systems and a close-to-hazard selection of meteorological situations, with a lot of small fast-evolving systems.

According to both subjective approach and objective performance scores, first analysis of the Cayenne campaign showed relatively good matches between RDT cells and in-situ high IWC areas. However, as seen in Darwin 2014 or cayenne 2015 campaigns, RDT appears sometimes to stop the diagnosis of convective cells too early compared to the lifetime of high ice crystal concentration and sometimes lifetime of convection.

**Conclusion and way forward**

In the framework of the HAIC project, the RDT has been operated by Météo-France over the different field campaigns on an operational basis through dedicated processing chains. The RDT has been used for ground operation and uplinked to research aircrafts.

Qualitative and quantitative studies provided reasonably good results, especially in terms of probability of detection of high IWC with the campaigns data. A comparison of RDT output with LEO satellites retrieval of IWC risk has also been performed. RDT reached the level 5 of TRL (Technology Readiness Level) procedure used in the HAIC project to assess the degree of maturity of a technology. The TRL6 contribution of WP3.4 has included identification and development of new RDT prototypes that will improve the RDT performances in high IWC detection.

Considering the good performances of RDT, the last NWCSAF release of the product (v2016) includes an attribute describing IWC risk inside each cell [Autonès et al, 2016], inspired by the algorithm MSG-CPP High IWC mask developed by KNMI at a pixel based during HAIC projet [Meirink et al, 2016].

The RDT v2016 is now produced by Météo-France on a global scale with five geostationary satellites: a new service for forecasters and for aviation end-users [Moisselin et al, 2017a].
References


Gounou, A., Moisselin, J.-M., Autonès, F., 2016, HAIC Deliverable D34.2 – The RDT Production chain for the Cayenne Campaign, HAIC-Project

Meirink, J.F., de Laat, J., Parol, F., Nohra, R., 2016, Deliverable D32.5 – Evaluation of SEVIRI retrieval of high ice water content environments with satellite data, HAIC project

Moisselin, J-M., Gounou, A., Flouttard, A., Autones, F., Flouttard, A., Carnino, D.; 2016, HAIC Deliverable D34.3 MET Support and training for Cayenne Campaign, HAIC-Project

Moisselin, J.-M., Gounou, A. Autonès, F., 2014, Deliverable D34.1 – RDT production chain implemented at MET-FR, HAIC Project


Moisselin, J.-M., Rieu, P., Le Bot, C., Gounou, A. Autonès, F., 2017b, HAIC Deliverable D34.5 Report on performance evaluation of the application for detection and nowcasting of high IWC regions for all HAIC field campaigns, HAIC-Project

Schwarzenboeck, A., Esposito, B., 2014, HAIC Deliverable D13.2 Final definition of HAIC flight tests aircraft payloads for WP2.2

Acknowledgement:
HAIC project has received funding from the European Union’s FP7 in research, technological development and demonstration under grant agreement n°ACP2-GA-2012-314314.